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Applying UGV technology to USVs

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Discussions

- Project Purpose
- USV platform
- Technologies Transitioned – H/W and S/W
- Command and Control
- Autonomy and Sensors
- Conclusions and Future Work

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Purpose

- Transition and develop technologies to advance the state of the art in USVs
  - Navigation
  - Autonomy
  - Not a platform development program
- Working to transition technologies from UGVs
  - Millions of dollars spent on research for UGVs
  - USV problem analogous to the UGV problem in many ways
    - Mostly planar navigation
    - Driving a boat is not that much different than driving a car

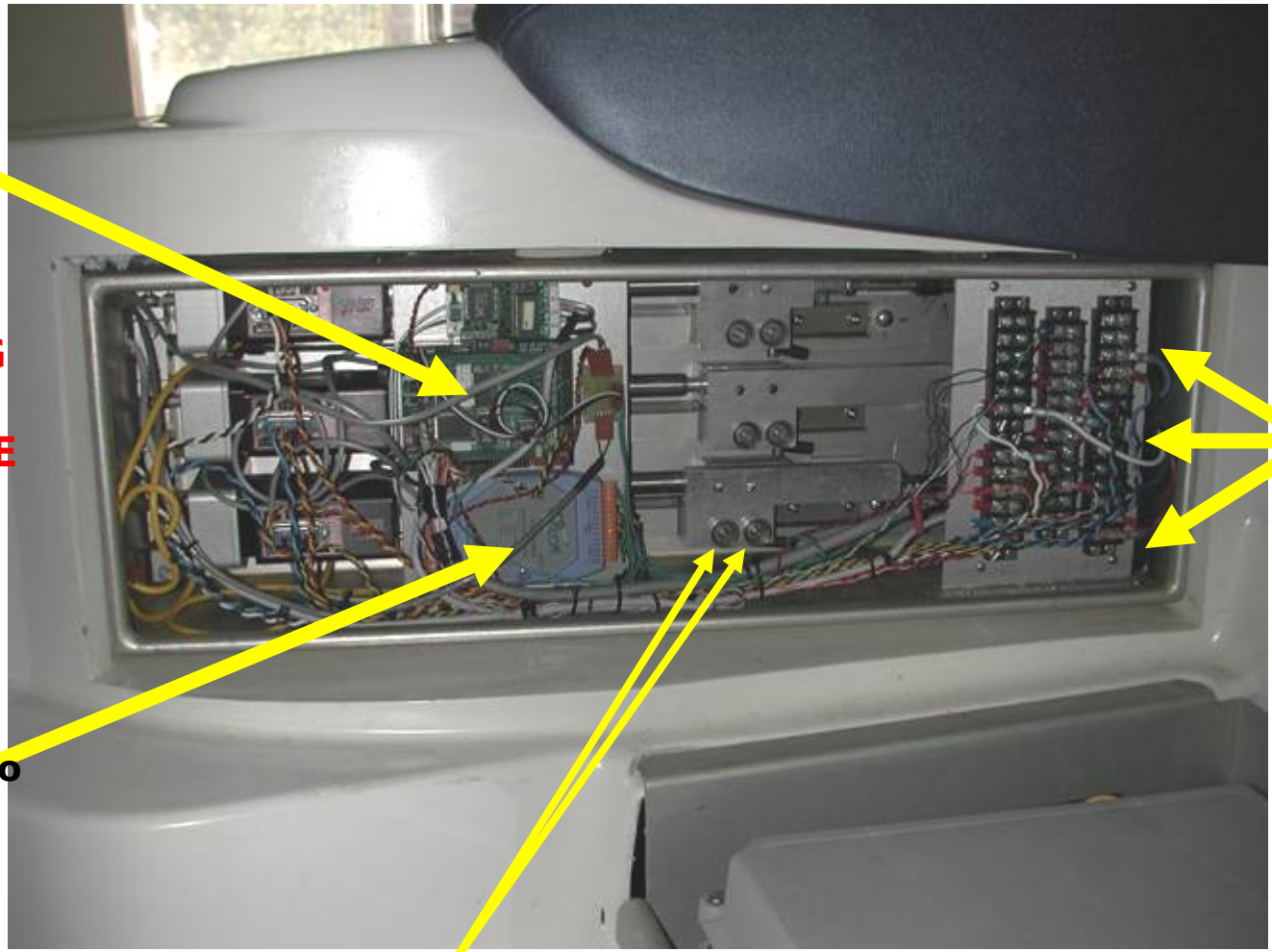
R&D Platform

- Platform choice based on cost, size, supportability, easy of integration and safety
- SeaDoo Challenger 2000 jet boat - Length 20’, Beam 8’, 2,000 lbs
- Payload capacity 1,400 lbs
- 250hp Mercury jet drive
- Max Speed 45kts

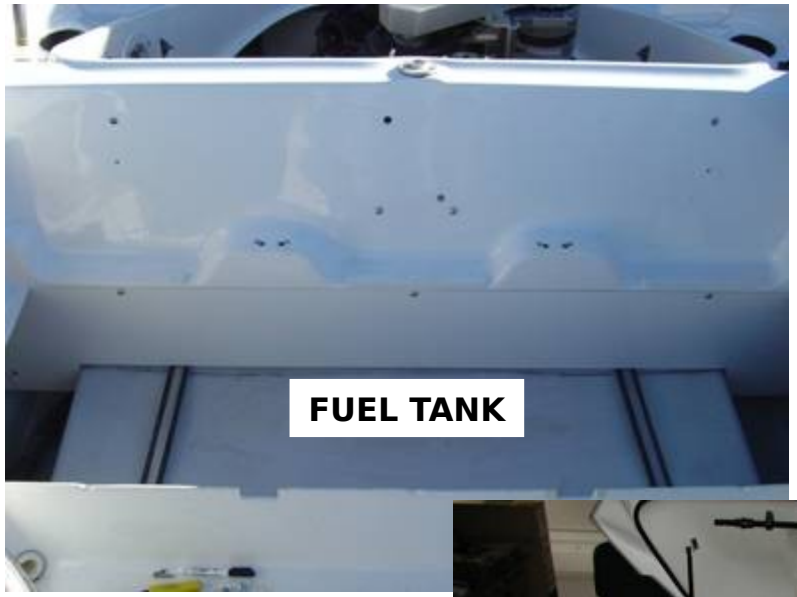
Platform
HM&E modifications

- Auxiliary power
  - 145 amp 24VDC generator
  - 24V battery bank
  - 24/12VDC converter
- Actuators
  - Three Ultra-motion Smart linear actuators for steering, throttle and bucket
  - Actuator compartment splits the organic flexible control cables
  - Three distinct operating modes: 1) Manual – fully mechanical linkage, 2) Drive-by-wire – Helm controls connected to sensors to control actuators, 3) Computer – tele-operation or waypoint navigation
- Sensor and equipment tower
  - Large-diameter, thin-wall stainless steel
  - Supports radar, electronics box, stabilized sensor/camera platform and cameras
  - Antennas
- Modular Electronic Bay
  - Three watertight enclosures
    - Power management
    - Communications
    - Navigation
- Cooler Bay
  - 120VAC inverter
  - Radar processor

Platform
HM&E modification
Actuator Compartment



Platform
HM&E modification
Modular Electronics bay under rear seat



Fiberglass Mods

Electronic Boxes

Installed Boxes

Completed Installation

Platform
HM&E modification
Sensor Tower

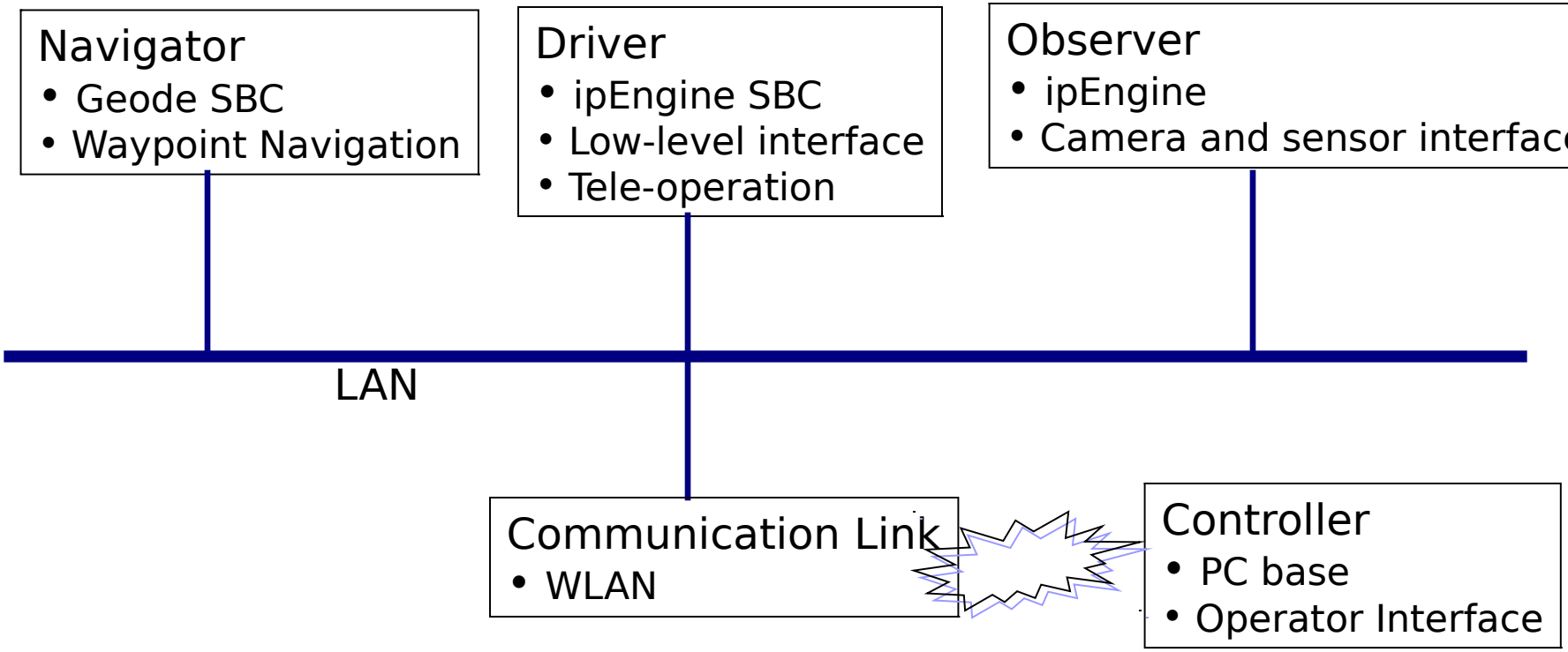
Motion Picture Marine Perfect Horizon

Transitioned Technologies
Hardware

- Processors, video CODEC, GPS, compass/gyro
  - Same components used for the MPRS URBOT
  - Short integration time
  - Processors
    - Brightstar ipEngine (PowerPC)
    - National Semiconductor Geode
  - Video CODEC
    - IndigoVision VP604 miniature H.263 video encoder/decoder
  - Novatel OEM-4 GPS (L1 only)
  - Microstrain 3DM-G gyro-stabilized compass

Transitioned Technologies

Architecture



SMART software architecture

• Domains (Navigator, etc) treated as independent domains or "agents"

• Dynamic registration

Moving to JAUS in summer of 2005

Transitioned Technologies
Software

- Tele-operation
  - Simply modified the actuator interface module
  - Functional within days of having hardware installation complete
- Waypoint navigation
  - Kalman Filter
    - Same KF as used on URBOT
      - Removed odometry input (haven't interface to the paddle wheel)
      - Tuned covariance matrix
      - Works well when boat has some forward velocity
      - No separate state for course and bearing (issue only when boat is stopped and drifting, using a dynamic covariance matrix)

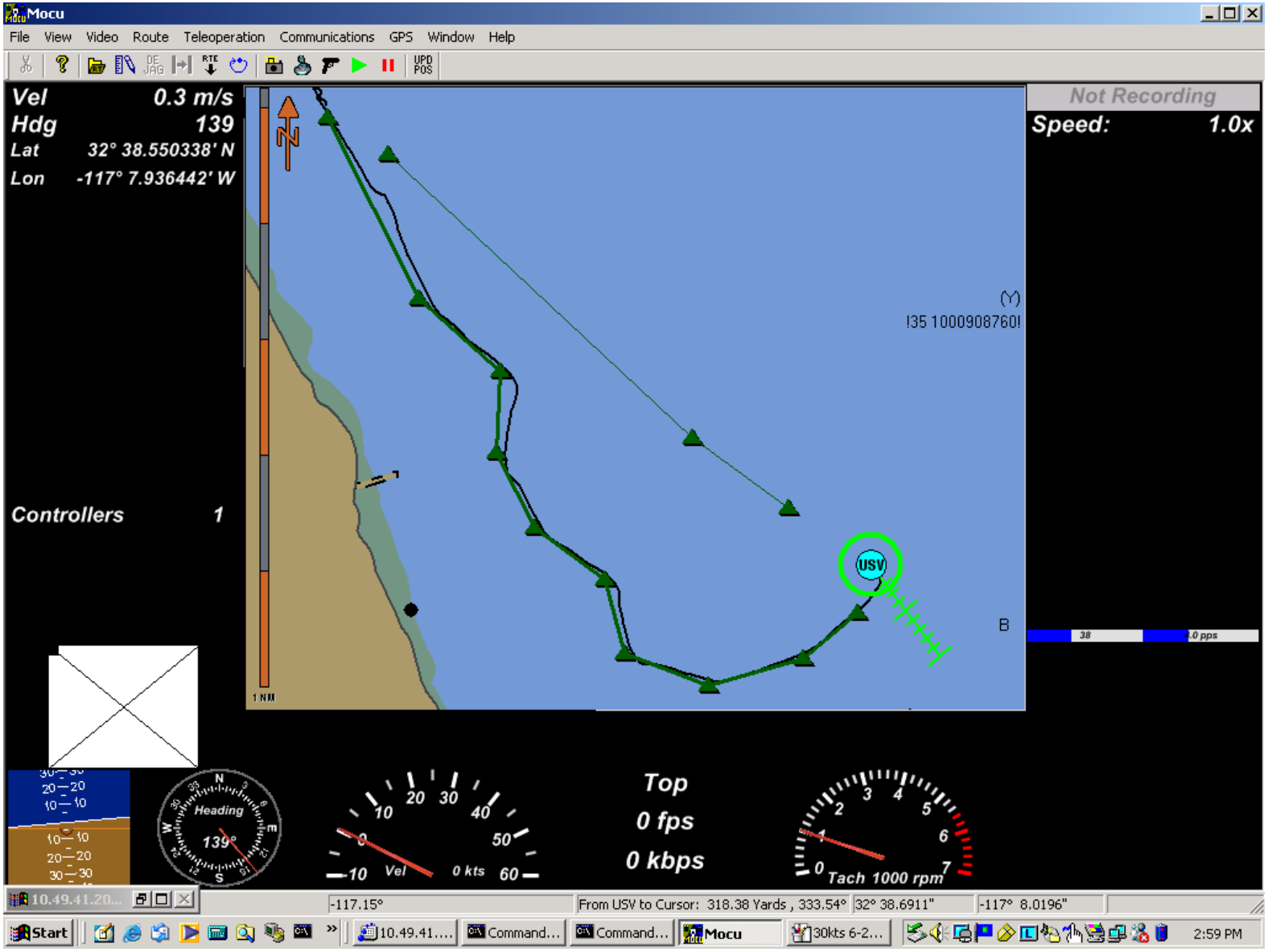
Transitioned Technologies

Software

- Path-following
  - Same pure-pursuit algorithm as using on the URBOT
    - Tuned PID gains and look-ahead distance
      - Boat is much less responsive than a skid-steer vehicle
      - Significantly different responses at different speeds
        - » Table for PID gains and look-ahead distance based on speed
    - Added a feedback control loop for velocity
      - Speeds near the planning speeds can be difficult to achieve
  - Were following routes at moderate speeds on the first day of testing
  - Very slow speeds are still a challenge
    - Wind and current have a much greater effect
    - Not much steering authority at idle speeds with a jet drive

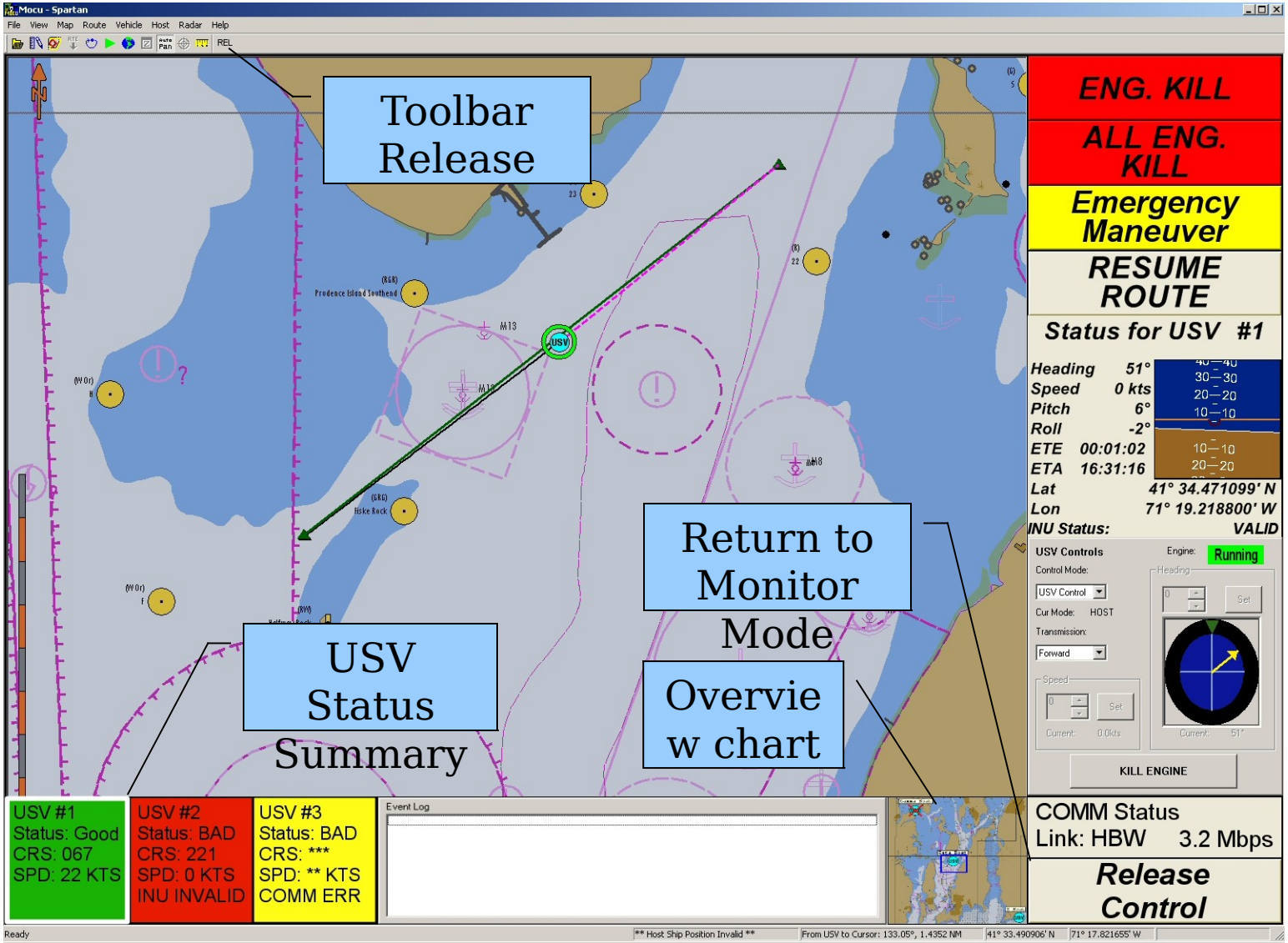
Transitioned Technologies

Command and Control



Transitioned Technologies

Command and Control



Autonomy and Sensors

- Autonomous obstacle avoidance and route planning
  - Radar
    - Primary sensor for marine navigation
    - Xenex Digital radar
      - Provides raw radar data and ARPA contact/track data over and IP in[illegible]

    - Issues with radar
      - Slow update rate
      - Minimum range of ~100m

Autonomy and Sensors

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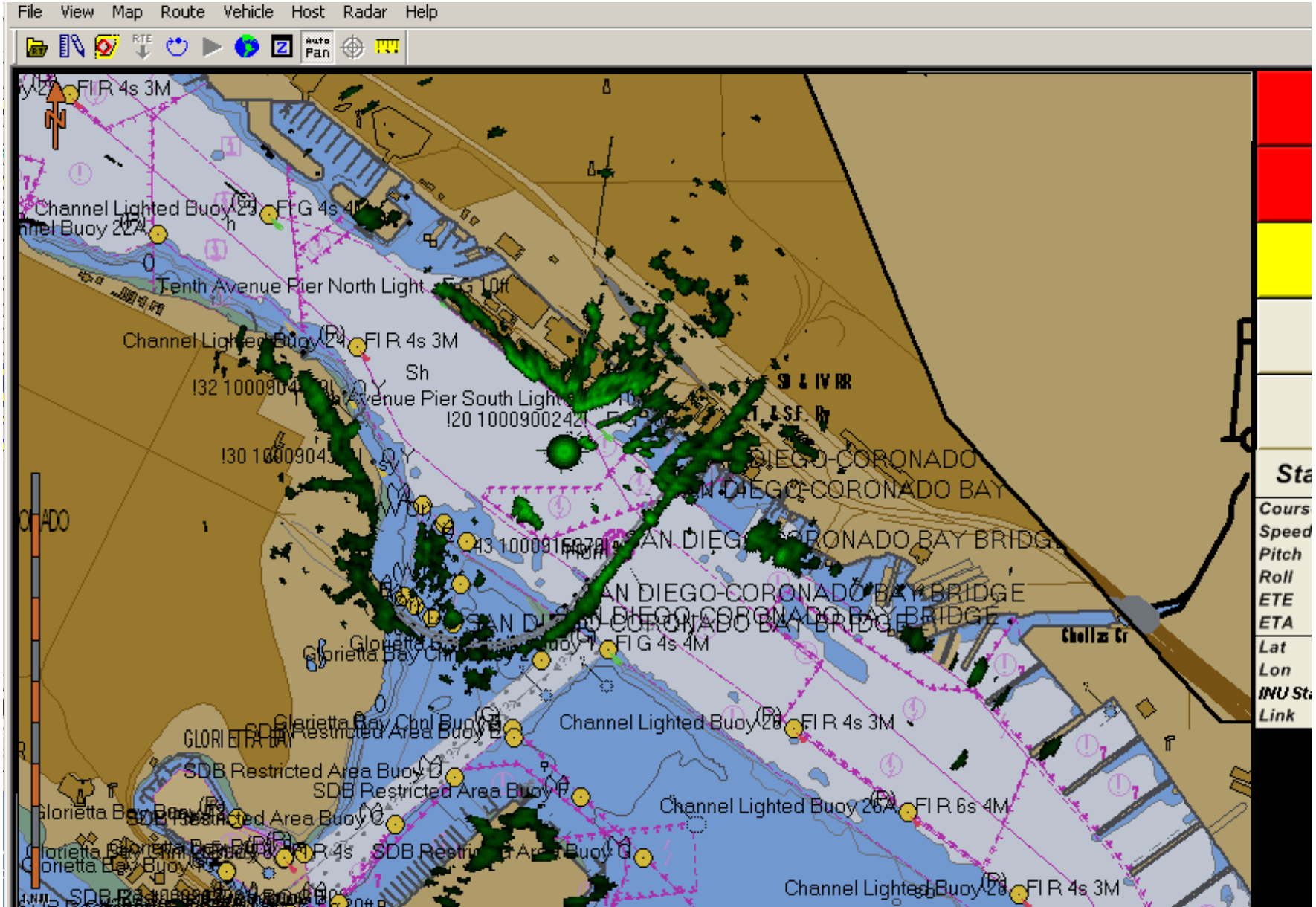
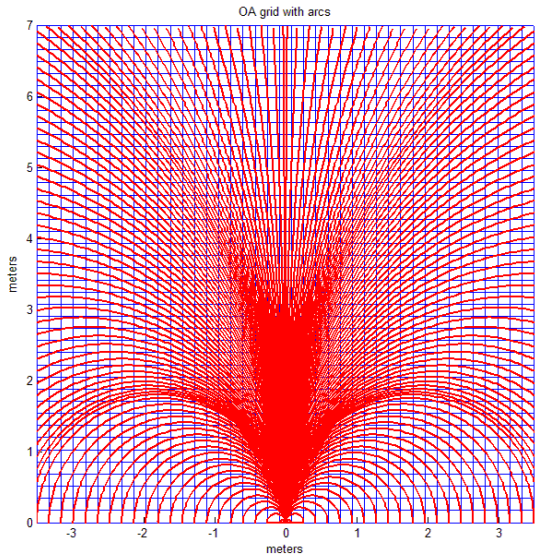


Autonomy and Sensors

- Investigating possibility of augmenting radar
  - Vision
    - Working with JPL to experiment with wide-baseline stereo
  - LADAR
    - Initial experiments with SICK look promising
  - Digital Charts
    - Fuse with radar
    - Use for route planning

Reactive obstacle avoidance

- Implementing the same reactive OA architecture as being used on the UGV platforms
  - Code re-use
  - Greatly expanded obstacle map
  - Developing behavio
    road”



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Conclusions

- Successfully transferred both hardware and software technology from the UGV to the USV
  - Significant savings in integration and development costs
  - Able to quickly demonstrate basic tele-operation and waypoint navigation
- Future work
  - Obstacle avoidance
  - Improved route following
    - Adapt controller for environmental conditions